The Long Term Impact of Digital Technology on Growth, Development and Prosperity

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Executive Summary

Perceptions of the digital economy have shifted dramatically in the past decade. Ten years ago, digital technology was perceived as a sector of the economy and a set of novel services, and markets. Today, and looking forward, it is viewed as a key part of the foundation of the entire economy. And this is true for a full range of economies, from lower income, to middle income and developed economies.

Digital technology is also viewed as a key element in defense and national security. This agenda then intersects economic and social agendas and creates tensions both within countries and across national boundaries with respect to trade, investment, knowledge transfer and technology.

The world has operated for a long time with GDP as the main measure of economic prosperity, but is moving reluctantly toward a multi-dimensional view of prosperity. Measurement of progress is following this trend. This slow moving trend is being driven by an awareness that much of what people care about is not captured by or even highly correlated with measures of material wealth. A non-exhaustive list of widely shared dimensions of well-being not captured in growth data would include at least the following: health, education and access to knowledge, longevity, economic security, options or choices for work, contributing to society in some way that is recognized and valued, the quality and

stimulation derived from work, leisure and creative activity outside or partially outside the narrow confines of the market economy, equality or its absence, fairness, and the effects on political and social cohesion, sustainability of growth patterns, intergenerational fairness (closely related to the sustainability), the environment and its contribution to the quality of life, and more.

That said, material wellbeing as measured by GDP or income per capita continues to dominate. In part this is because there is not yet a broadly agreed on single alternative to GDP per capita, nor a set of measures that better capture distributional and sustainability dimensions of progress (or its absence).

Digital technologies will impact all of these elements of well-being. So if we are interested in the long term impacts of digital technology on prosperity, the multi-dimensional framework is important. Digital technology will have a massive positive effect on human well-being across the world. Much of that progress will not be captured in conventional measures of material well-being and growth. Hence the multi-dimensional mindset in assessing economic and social progress is essential to capturing the potential of digital technology, and to guiding regulatory policies and investments designed to achieve the full potential.

Digital technology is also disruptive. While the long term net benefits are large, the process of getting there will not be Pareto improving (everyone benefits). Indeed part of the challenge is to come as close as possible to achieving the Pareto standard as possible.

To be clear, we do not argue that digital technology will have no impact on productivity and incomes. The argument is that the impact of digital technologies

on growth as conventionally measured, whatever its turns out to be, is likely to be only a small fraction of its overall effect on economic and social progress.

There are several reasons why the impact of digital technology is unlikely to be captured by GDP and related measures.

Digital technologies are delivering a vast and growing array of services to a large and increasing share of the world's population. The arrival and spread of the mobile internet was a key factor in expanding access. You don't have to be well off to use the digital channels of communication, email, social media, phone and video to stay in touch with family or friends. Ditto finding support groups for those others facing the challenge of dealing with Alzheimer's or other forms of dementia in the family. Or to access increasingly accurate and up to date weather information and market price information to informed decision-making in agriculture.

Most people in developed countries and a growing fraction of people in developing countries carry around an affordable 1980's level super computer, in their pockets, connected to a high-speed networks and most of the world's data which is in digital form. They can phone or video with their family and friends at negligible cost. They don't get lost. They can hail a ride easily even when taxis are hard to find. They have access to the world's information, images and data thanks to powerful search engines. Translation services are accessible, free and with advances in AI, rising in quality .Information services abound: weather, travel, health. They can find products and shop, with delivery in the near future. If you are in the open ocean far from any cell phone tower, essential safety

information about storms, lightning strikes, their location, and severity and direction are beamed down from the same satellites that deliver satellite radio.

These are digital services delivered directly to "consumers" and citizens, and they are essentially free. They are free for a good reason: the marginal cost of delivering them is essentially zero.[1]Hence they are largely properly priced. Since they are free, they will not appear in GDP measures, because the latter are based for the most part on market transactions, or when they are not available as in the case of government services, on cost. The providers of these services, prominently a subset of the mega-platforms, have alternative sources of revenue and profit (mainly targeted advertising).[2]

Second, with the advent of the modern version of AI, key service providers like doctors, will operate with a growing array of digital support systems or digital assistants. Some of these "digital assistants" will have super-human capabilities. The overall effect will be to enhance the quality of health care at relatively little incremental overall cost. Progress of this type will largely not show up in GDP growth.[3]And the digital technologies will not displace doctors and nurses. The digital technologies are not substitutes for the medical professionals, but rather

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[1] Recent estimates of the value of these free services are very large."Using Massive Online Choice Experiments to Measure Changes in Well-Being," Erik Brynjolfsson, Felix Eggers, Avinash Gannamameni, National Bureau of Economic Research, Working Paper 24514, April 2018.

[2] Free provision of services expands the user group and makes it hard for potential entrants to use price as an entry tool to overcome the network effects.

[3] Attempts to adjust GDP figures for quality increases, especially those achieved at relatively low incremental cost have been largely unsuccessful. See "Underestimating the Real Growth of GDP, Personal Income, and Productivity," Martin Feldstein, Journal of Economic Perspectives, Volume 31, Number 2, Spring 2017

service-enhancing complements. Widely deployed, the average costs of these augmented services will be low and the marginal costs even lower.

Digitally enabled and AI augmented eCommerce markets have had transformative impact on China's retail industry, vastly expanding the choices of consumers and empowering them in numerous ways- price comparison, convenience, deliveries and more. They show great promise in other developing countries, of enhancing inclusive growth patterns by augmenting access to markets, for consumers and small and medium sized businesses in less developed regions. A recent study from the Luohan Academy documents the inclusiveness of the growth patterns associated with eCommerce, mobile payments and enabled financial services in China, a pattern that is replicable in other emerging economies.[4]Yes, the digital technologies contribute to growth by rapidly expanding access to the modern urban economy. But the most interesting feature is the distributional one; the largest benefits are in the lower income areas. In the area of eCommerce, mobile payments, and digitally enabled financial service, China's experience and leadership are of great importance for a broad range of developing countries.

Digital technologies are sure to be an essential element in progress toward sustainable growth patterns through multiple channels, including energy efficiency, efficient electricity distribution networks, smart cities, autonomous electric vehicles, transportation as a service and much more.

We tend to think of digital technologies (in fact all technologies) as delivering intermediate products and services. In economics, intermediate products are those

[4] "Digital Technology and Inclusive Growth," Luohan Academy Report, January 2019.

that derive their value from their role in producing final goods and services. Viewed this way, digital technologies do not make a direct contribution to material wealth. If productivity and growth do not rise much (the indirect intermediate productivity effect), then the digital technologies have relatively little impact.

There are three problems with the intermediate products view of digital.

One is that digital technologies do deliver valuable final services at very low cost as noted above: so the premise is wrong.

There are a broad range of popular uses of digital technologies that should be classified as final goods and services – think of e books, digital music, video streaming based on subscriptions etc. (I would also add online education, digital payments, locational services such as food deliveries and ride sharing)

Second, to the extent that digital provides intermediate services, the effect frequently is to enhance the quality of the final product (as in the case of the medical example above) and GDP figures do a terrible job of capturing enhancements in quality or closely related increases in the scope of available products, especially when they are achieved at low cost.

Third, there are aspects of digital technology associated with robotics and the automation of blue and white collar tasks, that are intermediate goods and have the potential to increase productivity. But achieving that potential takes a long time, because it requires changes in skills and human capital, business models, organizational changes and more.

This should not be surprising. Historians have documented in numerous past cases of technological disruption and transformation, long lags in achieving the full potential of the new technologies.

The potential of digital technologies to enhance well-being, properly measured, in multiple dimensions is enormous. But there are many challenges along the way. For the developed economies especially, shifting the mix of skills and countering adverse trends in the distribution of income are among the most important.

Digital technology like major new technologies in the past, shifts the relative prices of goods, services, labor in many categories or skill levels, and assets. These effects can be very large, and can create challenges and resistance. In labor, the effect is to elevate the relative value of skills associated with creating and advancing the technology and skills that are complementary to the digital technology and its applications. Conversely, the relative value of skills for which the digital technology applications are a substitute, decline.

The dual challenge then is to move the skills mix in the working population toward the complementary category, and to the extent possible, to move the digital applications in the direction of complementing the existing skills mix. Most of the emphasis right now is on the former, that is shifting the skills mix. But the latter can be important too.

eCommerce and Fintech as they have developed in China, and to some extent in other emerging economies, have been architected so as to lower the technical skills required to engage productively in the platform-centered ecosystems including financial services. This is done deliberately by the platform architects

for the purpose of maximizing accessibility and impact on both the consumption and supply sides. The effect has been advancement in growth and inclusiveness in the digital economy.

More generally, directing the technology to the extent possible in directions that reduce technical skill requirements for users, is an important and promising direction. This also is not a new idea. The personal computer took off in part because of the graphical user interface.

As to shifting the skills mix in the "complementary" direction, it is a work in progress. There is no broadly agreed on formula for success. And all developed countries exhibit elements of job and income polarization – roughly the relative reduction of middle income jobs and incomes and the expansion of higher and lower income groups. Automation and the elimination of routine jobs has contributed to this pattern. These distributional features of growth patterns have contributed to political and social fragmentation and polarization.

There is no silver bullet for dealing with this challenge. International experience suggests that no single sector can solve this challenge, and that a broad pattern of cooperation across business, government, labor, and the education sector, produces the most promising results. A well-developed social security system with low cost access to essential services, and an income distribution regime that counters rising inequality in short run market outcomes, appear to be critical ingredients in successful recipes. This is again not surprising. Periods of rapid technological change create economic insecurity and distributional effects that are substantially reduced by properly constructed social security systems.

There are other challenges associated with digital technologies, too many to try to cover in one essay. Many of them revolve around the handling of data, and especially security and privacy. Different societies are taking different approaches and paths, a pattern that is understandable, given diverse circumstances and value systems. But that creates international tensions and incompatibilities. And there remain unresolved issues, depending on one's location. Does the right to privacy extend to the point that it facilitates money laundering, funding of terrorist organizations, and tax evasion on an international scale? Does the right to free expression remain intact in the face of adverse effects on political and social stability and cohesion?

For developing countries with incomes below the middle income range, digital represents both a big challenge and a significant opportunity. On the one hand, robotics and automation is in the process of displacing labor-intensive process-oriented manufacturing and assembly. That undercuts a key element of the known growth model for these countries, namely the source of comparative advantage. On the other hand, digitally enabled eCommerce systems, mobile payments, and financial services have the promise of accelerating growth and inclusion in highly beneficial ways.

In summary, the potential of digital technology to advance well-being in many dimensions is very large but not uniformly positive for all groups and in all dimensions of well-being. Much of the impact will not be captured by conventional measurements of material progress: GDP and its offshoots. A multi-dimensional approach and especially an awareness of the severe limitations of the

GDP in capturing advances and value creation in the quality and scope of products and services, are essential.

It would be all-too-easy in the present context, to frame things in a negative way: mainly by focusing on real challenges created by digital technologies (distribution and inequality, skills mismatches, monopoly power, misuse of data, cyber-security), while noting the limited evidence of progress based on measures like productivity, and ignoring or minimizing benefits in other dimensions. The huge collection of free and low cost digitally enabled information, communication, entertainment, and market-related services are dismissed by some commentators as insignificant.

In our view, it would be a colossal mistake to develop regulatory and policy responses and business strategies around this kind of negative framing of the issues. Countries that do so would risk falling behind. Real progress in welfare would be diminished. Companies that focus more on the disruption and uncertainty and less on the opportunities may fall by the wayside.

There is a widespread view that technological progress is inevitable and unstoppable. It marches forward on its own. Policy should then focus mainly on minimizing the downside risks. That view is at best only partly true. Regulation, incentives, human capital, investment in science and technology, and social values all matter in governing the rate and direction of progress.

It is unwise to focus mainly on either the benefits or the challenges. They go together and we need to do both. Addressing the challenges in a vigorous and pragmatic manner will materially help create an economic, social, and political

context in which the longer term benefits and future innovations can be fully realized.

Introduction

Much of the recent writing about digital technology generally and the modern versions of AI and machine learning, focuses on two things. One is the lack of evidence of these technologies impact on growth and productivity. The second is a host challenges relating to inequalities in growth patterns, difficult transitions in skills in the workforce, the management and ownership of data and privacy issues, cyber security issues in several dimensions, potential abuses of market power among the mega-platforms, regulatory issues specifically in the burgeoning are of digitally enabled finance, and both positive and negative effects of digital technologies on childhood cognitive and emotional development.

These are important issues that deserve serious attention and research. But the overall tenor of the discussions leaves the impression that the negatives are large, and the positives are elusive, in terms of measured effects. This overall picture is seriously misleading. We believe that properly understood, the long-term effects of digital technology on well-being, broadly and properly defined, are likely to be enormous, even though they are difficult to forecast precisely. Very few foresaw the breakthroughs in Artificial Intelligence of the past decade, for example. A failure to take a balanced view of benefits and challenges could lead to serious policy mistakes in terms of over-regulation and under-investment. We think the biggest risk lies in focusing only on GDP and growth and ignoring the benefits in many other dimensions of well-being.

Thus, in this essay, we try to focus on the potential long-term impact of digital technology.

One might think that the main issue would be the digital impact on long term growth. But narrowing the focus to growth is, we will argue, a mistake. It has become increasingly apparent in the past few years that digital technology will have a profound influence on well-being in many dimensions, only some of which, and perhaps even a small fraction of which, will be captured by growth as conventionally measured, that is growth in GDP.

A clear implication is that the multi-dimensional measurements of progress and well-being are essential. It is widely recognized now that well-being cannot be captured in a single measure. China has shifted from a singular focus on growth in GDP to a broader assessment of progress that includes environment, health, economic security, and sustainability among others. The developed economies, facing adverse distributional trends in growth patterns, sustainability issues, and more have also started to understand that material wealth as measured incrementally by per capita income captures only one element of well-being. But there is a persistent tendency to fall back to GDP.

What are these the dimensions of well-being that digital technology will advance? And why are the effects of digital technology on long term well-being so difficult to measure, relative to innovations of the past?

A non-exhaustive list of dimensions of well-being not captured in growth data would include these: health, longevity, economic security, options or choices for work, contributing to society in some way that is recognized and valued, the quality and stimulation derived from work, leisure and creative activity outside or partially outside the narrow confines of the market economy, equality or its

absence, and its effects on political and social cohesion, intergenerational fairness (closely related to the sustainability of growth patterns) and more.

Of course, if all these other dimensions and their measures were highly correlated with income, then as a first approximation, it would make sense to focus on income, growth and related measures like productivity. The problem is that they are not at all highly correlated, and to the extent that they are positively correlated, that correlation declines as income levels rise.

You could plausibly argue that in poorer developing countries, rising per capita GDP (and per capita income) is a necessary condition for achievement of sustainable progress on a broader set of measures of prosperity or welfare. That is a good argument for taking growth seriously, and making it a central focus of policy. But even that does not assure a high correlation. There is a big difference between necessary and sufficient conditions. It is not hard to find examples of high growth combined with suboptimal performance in areas like health and the environment.

Although there are now and will continue to be challenges in fully realizing the potential of digital technologies, their long run impact on well-being broadly defined and properly measured, is almost certainly going to be positive, very large, and in the end, highly inclusive. But only a fraction, and perhaps a very small fraction of that impact will be captured by GDP and conventional measures of economic progress.

If you read the popular commentary, a mixed picture emerges. The “digital superpowers” to use Kaifu Lee’s term, are China and the US. They are engaged it

is said, in a race for digital technological supremacy. There are defense and national security consequences of being in the lead or falling behind. Europe is falling behind: public and private investment in digital in Europe falls well short of the leaders. Europe also lacks domestic mega-platforms where much of the progress in AI applications is taking place

China is committing state resources to advancing digital frontiers, the externally controversial (and mislabeled) “Made in China 2025” being a symbol. China acknowledges that digital technologies exert powerful forces not only on the economy, but on the informational underpinnings of society, on the information flows that influence opinions and attitudes. China, via the Communist Party, will regulate these in pursuit of political and social stability. Some in the west view this as dangerous, a digitally turbo-charged version of what is sometimes called the surveillance state. Chinese policy makers however, look at the west with its patterns of rising political and social fragmentation, and conclude that is not necessarily the model they wish to follow.

The US and the west more generally is less committed to high levels of public investment in digital transformation., even though much of this technology emerged initially from defense and military initiatives. The west also understands that digital technology profoundly influences societal structures and political processes, but essentially has no answer to the question of where the responsibility for political and social stability resides, if anywhere.

In addition, in the west, rising patterns of income and wealth inequality, the huge valuations attached to digital superstars, principally the mega-platforms, and modest evidence of any impact of digital technologies thus far, on productivity or

growth, are at risk of undercutting the commitment to digital transformation. A blizzard of issues related to privacy, misuse of personal data, fake news, some of it emanating from foreign sources, cyber security, theft of intellectual property, cognitive development of children, potential deep biases in machine learning algorithms, and major disruptions in sectors like retail, have shifted the popular image of digital in a negative direction. This shift has occurred very rapidly in the past couple of years.

In the corporate sector, digital transformation holds promise, but also carries with it anxiety and threats associated with disruption, loss of competitiveness and falling behind.

Lost in complexity of the challenges and the international competition for technological leadership, and in the natural anxiety of digital disruption in the corporate sector, are the huge strides in well-being that can be achieved. Even in the developed economies, the potential of digital enhanced services are very large. In the relatively near future, medical services will be augmented in terms of quality by digital assistants (some of which are superhuman in capacity) who are complementary to medical doctors and nurses. The result will be significant increases in the quality of medical services and health care, with marginal if any increases in cost. And the results are nearly certain not to show up in growth or productivity data, not just now, but ever.

I. The Evolution of Thinking about Digital Technology

Ten years ago, digital technology was viewed as a sector or a collection of sectors. This is no longer true. It is now viewed, correctly, as a key element in the

foundation of the entire economy. All economies of course have informational structures and foundations, without which they do not function. These foundations have tended to receive less attention (at least until recently) than the physical foundations and infrastructures. Digital technologies are transforming the informational foundations and structures of economies, markets, organizations, societies, political processes.

Why is it important not to focus on solely on conventional measures of economic progress?

Diagnosing Skin Cancer via AI and Image Recognition Technology

We begin with a simple recent example of the application of AI, specifically image recognition. Recently at Stanford, AI has been used in collaboration with dermatologists to train an AI system reasonably accurately to recognize various forms of skin cancer. It works pretty well. There was some hard work assembling the training data set. It leverages the substantial image recognition technology and investment in this case by Google, but also others. The image recognition engines are a powerful general use technology with literally thousands of applications, this being just one. [5]

The "Automation" mindset might lead one to think that the technology will replace dermatologists. That won't happen. Image recognition systems do not

[5] Autonomous vehicles and robots that can do electronics assembly being better known cases. Note the embedded huge economies of scale and scope associated with the application of this kind of general use technology.

excise carcinomas or perform operations to deal with melanoma. It is more likely that dermatologists will use it as a tool to enhance the quality of their work. The machine acts like a colleague delivering a second opinion. And in any case, the dermatologist still has to decide on treatment options and then carry them out. And in some cases, follow on work in the form of biopsies may be indicated.

One might be skeptical of the benefits of a technology that can almost match dermatologists in diagnosis of skin cancers. That might be true in the world's major cities. But a very large fraction of the world's population doesn't have easy access to dermatological services. That group will be able to use the camera in their phone, to scan for skin cancer risks. And if those should appear, they can decide to incur the expense (in terms of cost, distance and time) of seeking diagnostic and treatment help from dermatologists who are not local.

In a sense, this AI application serves the function of a routine check of the type that many in highly developed centers carry out in person. It doesn't replace the doctor. Instead at least potentially, it dramatically expands the feasibility of preventive care and early screening to most of the people on the planet.

Assuming all this comes to pass, will it show up in higher growth and expanded productivity? Perhaps a tiny bit. Whatever that increment turns out to be, will it capture the benefit in terms of reduced risk of serious, and sometimes life-threatening illness, for millions of people. Clearly not. Will the livelihood of dermatologists be threatened by displacement with machines? Very unlikely. The machines are complements to rather than substitutes for the doctor. In fact, the opposite could occur. Dermatologists could experience a boom in their practices

as people who were formerly out of the system show up for diagnosis and treatment at earlier treatable stages.

This is not an isolated example. Similar technology is being used to interpret scans for diabetic retinopathy, that can lead to blindness if left untreated. Systems that do this are being tested in India, Europe and the USA. The AI in the India case is particulary impactful, because an estimated seventy million Indian citizens are diabetic and there are 11 eye doctors per one million Indians. The hope is that the digital AI system will expand the diagnostic capacity of the system, and allow ophthalmologists to focus their time and expertise more on treatment and less on diagnosis. Humans/doctors are still better than machines at diagnosis. Apparently cataracts can blur the images and at least for now, confuse the AI systems.

There is good reason to believe that digital technologies, and specifically the modern version of AI, will produce dramatic increases in the quality and accuracy of medical diagnoses. Not only because of pattern recognition with respect to images, but because AI's can "read" a vast literature in a tiny fraction of the time that it would take a human, and direct doctors' attention to the key articles and findings. The machines are super-human in certain dimensions such as this, and that enhances the quality of diagnosis and doctors' choices about treatment.

Doctors and the medical profession generally will be equipped with digital assistants, that are not all that costly and that enhance the quality of diagnosis, drug discovery, surgery, and the finding of the genetic exposures to some diseases.

The question then is, will this contribution to well-being be fully captured in an increment to GDP per capita. The answer, fairly obviously, is no. It will mainly

result in higher quality health care with minimal if any increase in cost. Is the primary purpose of committing resources in this area (the NIH in the US has the largest public funded budget for research) to augment material wealth? No. Will doctors be put out of work or rendered redundant. Probably not though they will likely change how they allocate their time, essentially to activities that are complementary to the digital machines.

Why do we have a tendency to focus on GDP in thinking about technology impact.

For example, there is much current discussion of declining measured productivity in the face of what brilliant new technologies (lags, measurement, maybe digital is no big deal after all).

Part of the problem is a persistent tendency to think of digital technologies (in fact all technologies) exclusively as generating an intermediate products or services, that is goods or services that are used to produce things that people purchase, consume and value, but that have no final value in themselves. The value of intermediate products derives from the contribution to producing things that consumers do value. If you think about digital technologies (or any technology this way) then its economic contribution has to come from having a positive impact (via lowering the cost or enhancing the quality) in the production of final goods and services.

Of course, digital technologies do produce intermediate goods and services. And that will have productivity effects – but with longer lags that most anticipate – and eventually show up in measures of real income. But they also produce a host of services that people directly value.

The key point is that digital technologies prominently also produce final (that is valuable) services that are informational in character. Those services are missed by conventional measures because they are largely free. When paired with humans, they also produce increases in the quality of services, at very low marginal cost, as noted above in the case of health care.

Why are the digitally enabled new services and unmeasured quality increases essentially free? The main reason is that the marginal cost of accessing digital information is zero, and the opportunity cost of providing information to one person, for everyone else is zero. This last characteristic is a long-known property of information and knowledge. Provided there is a way to store information without depreciation or degradation over time, information is permanent and non-rival. Unlike physical goods. This is one of the principal reasons why the benefits, that is the positive impacts on well-being, tend to have a highly inclusive character. The cost of the marginal user of the information is zero. Digital technology has made vast amounts of information, communication services, and access to markets essentially free.

There is a growth literature, associated with the work of Noble Laureate Paul Romer and others that focuses on the power of information and knowledge in underpinning growth. It is a critical insight. Developing country growth in the post war period (at rates that are unprecedented – sustained growth at 7%or more for multiple decades) is largely explained by this phenomenon. Information, knowledge and technology, transferred and adapted from developed to developing economies in no way diminishes its supply and impact in the former. And now of course, developing countries themselves are becoming major producers of new

technologies that will also largely be shared globally. This is especially true of China.

Exactly the same principle applies to digital technologies. They operate in the information/knowledge/communication layer of the economy. They probably will elevate GDP growth eventually, but they will also underpin enhancements in many other dimensions of well-being.

You don't have to be well off to use the digital channels of communication, email, social media, phone and video to stay in touch with family or friends. Ditto find support groups for those others facing the challenge of dealing with Alzheimer's or other forms of dementia in the family. Or to access increasingly accurate and up to date weather information and market price information to informed decision-making in agriculture.

Most people in developed countries and a growing fraction of people in developing countries carry around an affordable 1980's level super computer, in their pockets, connected to a high-speed networks and most of the world's data which is in digital form. They can phone or video with their family and friends at negligible cost. They don't get lost. They can hail a ride easily even when taxis are hard to find. They have access to the world's information, images and data. Translation services are accessible and free. Information services abound: weather, health. They can find products and shop, with delivery in the near future. If you are in the open ocean far from any cell phone tower, essential safety information

about storms, lightning strikes, their location, and severity and direction are beamed down from the same satellites that deliver satellite radio.[6]

All of this has become available during a period of mostly modest growth and declining productivity growth, at least in the developed economies. While income growth in developed countries has been modest (or worse in some economies), depending on one's location and position in the income distribution, the purchasing power of those incomes has expanded dramatically, a proposition that is definitionally true for valuable services that are widely available and essentially free.

This is not in any way to dismiss concerns about adverse distributional trends in income and wealth and the possible ways in which digital technologies have contributed to these trends via the impact on jobs, tasks, and the demand and supply of skills. But the impression that digital technologies have caused major disruptions while contributing negligibly to well-being thus far, is simply wrong.

Recent research indicates that the value of the low-cost or free final services to consumers is very large. In a recent paper, Brynjolfsson, Eggers and Gannamaneni show that the users of digital free services like search, maps, social media, would require very substantial payments to give up the services for a specified period of time.[7]The set of services available is growing in range and

[6] One of us is old enough to remember rationing phone calls to family and home while in college to once a month, because of the cost. It is a constraint that is almost inconceivable to younger generations for whom information and communication services are free and a natural feature of the social order.

[7] "Using Massive Online Choice Experiments to Measure Changes in Well-Being," Erik Brynjolfsson, Felix Eggers, Avinash Gannamameni, National Bureau of Economic Research, Working Paper 24514, April 2018.

quality and clearly has value to all the users. Since none of this value appears in GDP figures, they conclude that well-being is advancing in ways that are not captures by the conventional measures.

Martin Feldstein, in an influential paper in the Journal of Economic Perspectives, argued that changes in the quality of existing services and the introduction of new goods and services are extremely difficult to measure and are poorly captured if at all in GDP figures. The result he says, is that real growth of GDP, income and productivity is persistently miss-measured and understated in the national accounts figures.[8]The implication is that GDP is supposed to capture these quality and new product effects, but that insurmountable measurement challenges and failures cause growth to be under-stated. Certainly persistent attempts to capture new products and quality increases have not yielded impressive results.

There is a subtle issue here. If one thinks that GDP can or should be a reasonably comprehensive index of well-being, then the measurement problems Feldstein describes are serious problems. The alternative is to move to a multi-dimensional view of well-being, and then to accept that not all advances will be captured in GDP, including but not limited to the ones that are the focus of Feldstein's paper. Since shoehorning all these advances into the national income accounting framework seems fraught with difficulty, our view is that the multi-dimensional approach is the more practical way forward.[9]

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[8] "Underestimating the Real Growth of GDP, Personal Income, and Productivity," Martin Feldstein, Journal of Economic Perspectives, Volume 31, Number 2, Spring 2017

[9] GDP, and growth are key statistics for certain important issues. For example, growth in GDP is a key factor in thinking about and dealing with debt overhangs, and in assessing the severity of fiscal imbalances – unfunded pension liabilities for example. For these purposes, we can't just abandon GDP and move to another measure. Even adjusting GDP for say the

Ⅱ. Storage, Data Access, and Updating

In the digital world, storage is important. Digital is not the only or the first technology for storing and accessing information and data, and knowledge. Before the digital age there were books, musical recordings, records and CD'S, films, mostly in analogue form. Digital is much more efficient. You can search for patterns in analogue data, but mainly by digitizing it first. Most of the world's data is now stored in digital form (books and writing of all kinds, video, music, speech, as well as of course, numbers (what is normally connoted by "data").Most of these things are accessible to a majority of the world's population. Not many decades ago, accessibility was confined to the few, mainly in developed countries. In focusing on one's own world and immediate environment, a tendency we all have, it is easy not to notice how incredibly inclusive the digital underpinnings of the global system are becoming.

Updating of data is also important, and so networks, their speed and reliability matter. A Dickens novel doesn't change much with the passage of time. But traffic on the roads and weather do. The digital technologies are transformative in part because feedback systems and updating of databases occurs very quickly and at very low cost. Important for maps, location services, real time weather information, whether stores and businesses are open or closed and of course the efficient management to supply chains.

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value of free goods would be problematic. That leads us to believe that the best course is not to replace GDP, but rather to augment it with additional measures that are designed to capture additional dimensions of well-being.

III. Inclusive Growth Patterns: Digital Ecommerce and Mobile Payments in Developing Countries

An important recent study by the Luohan Academy in Hangzhou highlighted the inclusive aspects of the growth patterns around the eCommerce and Payments/Fintech platforms.[10]The key points in this study are noteworthy and of potential significance for a broad range of developing countries.

Ecommerce platforms have evolved to be digital enabled ecosystems that drive growth in a highly inclusive way. The platform is the architect and coordinator of the ecosystem, or a coordinated and connected collection of market places for complementary goods and services.

The ecosystem facilitates entrepreneurship by lowering entry barriers dramatically in two ways. It expands the accessible market and it provides easily accessed complementary resources (logistics, fast manufacturing, marketing advice, and credit financing).In addition, on the consumer/demand side, in rural areas and lower income cities, the eCommerce platform provides access to retail that is otherwise inaccessible or underdeveloped.

There are about 10 million businesses on the selling side on Taobao. Most of them are small businesses including Daddy Mommy shops. Roughly fifty percent of the entrepreneurs are women. There are larger measured effects in terms of penetration and variety in lower income areas of the country; 3rd and 4th tier cities and the rural areas, precisely because the options with respect to conventional retail relative to major centers like Shanghai are underdeveloped.

[10] "Digital Technology and Inclusive Growth," Luohan Academy Report, January 2019.

The eCommerce platforms promote entrepreneurship and scaling of new businesses by expanding the size of the accessible market: the average distance between buyer and seller in the off-line world is 4 km. On Taobao it is 1000 km.

The mobile payments systems in China are way ahead of the rest of the world including developed economies. Mobile payments, initially developed in the online world to support eCommerce transactions, have expanded to the offline world. China is well on its way to becoming a cashless economy on the consumer side. And for much of the population, this has meant shifting from cash directly to mobile payments without passing through intermediate systems like checks, credit and debit cards. The mobile payment systems are highly efficient. The average cost to the merchant is about 0.6%

The combination of the ecommerce platforms and mobile payments systems have produced large and growing data sets on which to turn loose the Prediction algorithms that characterize modern AI. Accurate credit scoring, and inclusive patterns of credit extension to vast numbers of people, including potential entrepreneurs, who are essentially blocked out of the conventional banking-based system, due to anonymity: limited track record, and lack ofcollateral. As demonstrated by the rapid growth of Ant Financials, the world's largest FinTech company, the mobile payments systems enable the addition of an array of financial services. The marginal cost is low of adding, credit, asset management, and insurance. All of this is in process and have an inclusive character.

As these systems grow, cloud computing becomes an important scalable element of infrastructure. It is need as the volume of transaction sand payments rises especially at the peaks.

There are of course many regulatory issues like capital requirements, fraud prevention etc. In a period of major structural change, Regulators need to strike a balance between encouraging or at least not inhibiting innovation, and while moving alertly to limit various kinds of risks, some of which will be new.

The China experience is important for other developing countries. The creation of coordinated digital market places and the mobile payments systems materially enhance growth and do so in a highly inclusive pattern. Obviously these two are related. The faster relatively isolated or lower income regions are equipped with tools to join the modern economy (consumers on the demand and entrepreneurs on the supply sides), the higher will be overall growth. Or put simply, the inclusivity is a part of the growth engine.

The key question is what infrastructure does a country need to jump start this process. The mobile internet and universal access to it is probably the most important enabler. There are payment systems like Mpesa in Africa that use sim card registration and text messaging to facilitate mobile payments. This is an important step toward economic and financial inclusion. But this is not the full mobile internet and not enough to support the ecommerce piece.

Leapfrogging is a key element of this story in developing countries. On the technological side, a minority went through the conventional sequence of computers, internet access, mobile phones and mobile internet. The vast majority in China and in other developing countries will go from disconnected to mobile internet with enough speed to support ecommerce and all that goes with it. Similarly, on the financial side, the majority went from cash to mobile internet skipping checks, credit and debit cards. On the eCommerce side, in high income

cities, eCommerce is competing with, to some extend displacing, and now integrating with offline retail, much as Amazon does in developed economies. But in lower income regions, cities and the rural areas, eCommerce is the augmented retail sector. It is not competing with a large established offline retail sector. The latter doesn't exist.

The story about inclusive growth enabled by ecommerce platforms could and we hope will, have a regional/international dimension. For smaller countries, that do not have the kind of large homogenous market that one finds in China or the USA, international ecommerce can materially increase the accessible market especially for small and medium -sized businesses. And for poorer countries, international markets remain a key enabler of relatively high-speed growth patterns. Domestic markets are too small and too limited in scope to facilitate the kind of specialization that one sees in the "Asian" growth model cases. Realizing this potential will require a new kind of international cooperation to facilitate this kind of digitally enabled international trade in both goods and services. It should be a key part of the agenda of the WTO and multilateral development institutions.

Digitally enable trade is especially important now, because digital technologies in the form of automation and robotics are close to or at the point of displacing many labor-intensive manufacturing and assembly processes in terms of cost and quality. This undercuts the principal historical post-WII bases of comparative advantage for early-stage, non-resource rich countries.

Ⅳ. Automation, Augmentation and Disruption

Automation has been with us for some time. Numerous recent studies have documented certain facts that should inform any assessment of the longer-term impact of digital technologies on well-being.

Automation thus far has consisted mainly of automating tasks, and for the most part not whole jobs. Jobs in this context should be thought of as sets of tasks. Until the advent of machine learning in the past decade, automation consisted of having machines do routine manual or cognitive tasks, which had the property that we, humans knew how to do them, and we could describe precisely the steps required to do the task. The combination meant that we could code the steps enabling, at least in principal, a machine to perform the task.

Sometimes groups of tasks were integrated into systems that automated whole processes. An early and by now familiar example is ERP systems that automated the pieces of enterprise information platforms (general ledger, order processing, billing, etc.).This extended to managing whole supply chains and contributed to the efficiency and manageable complexity of global supply chains.

Amazon distribution centers use digital technology to manage the order flow, inventory management and the operations in the center itself. Robots guided by the computer systems bring stacks of inventory to stations where humans (still thus far) select and scan the item that is being prepared for shipping – picking and packing. Undoubtedly Amazon, like others, has introduced AI to improve the precision of demand forecasting all the way down to the likely behavior of the individual buyer, using the same or similar AI technology as is used in the recommendation engines to reduce search costs and increasing the efficiency of matching (interests and preferences with products) in the market places.

But the early form of automation here as elsewhere followed the older “codify able” model.

This previous generation automation has had substantial effects. It has taken routine jobs out of the economy. Slightly more accurately it has taken routine tasks out of the economy. The nature of specific jobs has shifted. The data for developed economies indicates that middle income jobs have declined while lower and higher income jobs have expanded. And those increases, in the tails if you like, tend to be in the non-routine category. This has resulted in a pattern of job and income polarization across the developed economies.

In fairness, some part of the polarization trends of the past two decades at least in the tradable portion of the economy (goods and services that can trade international and are subject to foreign competition) can be traced to specific patterns of globalization. But the pattern is very broad and covers the large non-tradable part of the economy (something on the order of 2/3 of a modern economy).Thus, the influence of automation is clearly substantial even if it is difficult to separate with precision from globalization.

I .Artificial Intelligence

There is little doubt that there has been a breakthrough of enormous significance in AI in the past decade. Essentially digital machines can learn to do some things that defy codification. Image recognition, understanding speech, translating from one language to another.

Combined with fine motor coordination, machine learning in several variants has dramatically increased the range of application of robots in production,

distribution, logistics, and other functions. Autonomous vehicles are possible now because of these breakthroughs.

Breakthroughs and progress continue to come at a rapid pace. It seems reasonable to assume that the range and magnitude of the impacts of AI, in spite of being substantial already, are in the early stages. Reading the voluminous commentary on modern AI, one might think that the main effect will be a huge increase in automation and job displacement and disruption.

While disruption is surely inevitable, we believe that the principal longer term effects will lie in the area of the range and quality of services that are available to people and organizations. And that as in the past, these increases in quality and availability will not be accompanied by substantial increases in cost. As a result, as in the recent past, they are unlikely to be captured in standard measures of productivity and GDP. But they do promise huge increments in well-being.

ii. Prediction Machines

A very useful and insightful recent book on the economics of AI, calls the current version of AI, prediction machines.[11]The word "prediction" in English has the connotation of something that hasn't happened and that may or may not happen in the future. But this book, and machine learning generally is not only about the future. The machines take large amounts of data, detect patterns, and draw probabilistic conclusions about what the data signifies. That is the sense in which they are making predictions.

[11] Prediction Machines: The Simple Economics of Artificial Intelligence," Ajay Agrawal, Joshua Gans, and Avi Goldfarg, Harvard Business Review Press, April 2018.

For example, in light of past purchasing and browsing behavior of an individual and everyone else on an ecommerce website, this person is likely to be interested in the following products. Or, based on data from X-rays of patients who turned out to have a particular kind of lung cancer, this person's X-ray indicates a high probability of having a similar form of cancer, or not. Or based on inbound data from mobile phones mapping functions, it is likely there is a traffic problem in a particular location.

These are predictions from data, but not necessarily about the future, done very fast and in some or even many cases with a precision that exceeds human capability. The authors make a convincing case that many tasks that people perform involve making judgments, based on data or information, about the state of the world, and then acting on those predictions. Prediction is part of performing many tasks, but not all of it.

iii. AI Powered Digital Assistants

Automation is a concept that comes from the idea that machines can replace humans in the performance of certain tasks. It is not entirely wrong, but it leads to an incomplete understanding the impact of digital technologies. In many applications of AI, the machines augment the humans. In all likelihood, we will see both Machines will replace humans in certain tasks, and in other cases, they will be digital assistants for working partners. Breakthroughs in AI, thought of as prediction machines, has certainly expanded the potential impact of digital technologies in both categories.

It is impossible to foresee the future applications of digital technologies. But there are now enough cases to give at least some indications.

Digital technologies and AI have increased the scope and efficiency of markets.

They are in the process of transforming the financial sectors, with beneficial effects in terms of access and inclusion.

Robotics has taken a giant leap forward and will continue to advance. That will transform manufacturing and logistics among other things.

Digital technology combined with AI powered search have delivered a host of valuable services: access to information, social interaction, entertainment, access to markets and financial services. Because the cost of acquiring information has dropped so much, less time is spent on acquiring it and more on analyzing it. The declining cost of information has also reduced to some extent informational asymmetries in markets.

Ⅴ Challenges and Issues

i. Productivity:

Digital based services are both intermediate and final products as noted earlier.

The final products matter, and because they are low marginal cost and often free, they do not get counted in growth.

But for the class of **intermediate** digital products and services, the benefits should show up in productivity figures.

The link to growth is slightly more tenuous, because people (especially in higher income economies) may work less for compensation, and allocate more time non-compensated activities that they enjoy, what is somewhat misleadingly referred to as leisure.

However, there is another transmission mechanism to growth for developing countries. As described earlier, for developing countries, digital technologies can increase growth via accelerating access to information and to markets, and thus increasing the speed with which lower income regions join and participate in the modernizing part of the economy.

Productivity data for developed economies thus far, do not indicate a significant digital impact. The exception was a spurt of productivity gains in the late 90's and early 2000's associated with expanding accessibility of the internet to businesses and individuals.

While some scholars believe that the reason for the lack of productivity growth is that the long-term impact will actually be small, that is probably a minority view.

An alternative view is more persuasive. It is that potential productivity effects are large but arrive with long lags. For example, studies by MGI and others indicate that digitization of businesses and processes, varies considerably by sector, with very substantial sectors in terms of employment (government, health care, retail, hospitality among them) lagging behind in implementing digital technologies.

In the corporate sector across pretty much all industries, there is a sense of urgency and some anxiety about understanding and implementing AI in the organizations and business models. That suggests that business leaders broadly

believe that AI and digitally enabled business models will be a key factor in their competitiveness in the future. But with the exception of some leading firms, adoption of AI powered business models and processes is at best in the early stages. In addition, the leaders in Ai tend to be the mega-platforms and these are prominently among the firms that supply free or low cost services, precisely the benefits that are barely captured if at all by standard national income accounting measures.

ii. Work and the Distribution of Benefits

Digital technology, like globalization, has distributional effects. It does this by shifting the relative prices of goods, services, labor, skills and human capital, and other assets. Labor is an area of particular focus. Here we use labor, not to refer just to blue collar workers, but to all work for compensation. That is CEO's and computer designers and hedge fund managers are part of the labor force.

Digital technology has raised the market value of work, or more precisely skills and human capabilities, that are complementary to the digital machines, and the value of work involved in creating the machines. It has lowered the market value of work for which digital machines are, or will soon be, a lower cost substitute. For example, entrepreneurial skills have increased in value in the context of digital enabled market places and ecosystems. On the other hand, robotics has reduced the relative value of certain skills in manufacturing and logistics operations.

What this means in practice is that labor skills at all levels need to migrate to those that are complementary to machines. Modern AI has expanded the

capabilities of digital machines and market places. Skills and tasks that were complementary to earlier digital technologies may migrate into the category of substitutes as digital capabilities expand. This means that the boundary between complements and substitutes is a moving target, increasing the complexity of the skills migration challenge.

It is also important to recognize that the machines can be architected to better utilize the existing portfolio of skills. The dual challenge then is to move the skills mix in the working population toward the complementary category, and to the extent possible, to move the digital applications in the direction of complementing the existing skills mix. Most of the emphasis right now is on the former, that is shifting the skills mix. But the latter can be important too.

eCommerce and Fintech as they have developed in China, and to some extent in other emerging economies, have been architected so as to lower the technical skills required to engage productively in the platform-centered ecosystems including financial services. This is done deliberately by the platform architects for the purpose of maximizing accessibility and impact on both the consumption and supply sides. The effect has been advancement in growth and inclusiveness in the digital economy.